Section III

Academic References

Yunus A. Cengel, Heat Transfer: A Practical Approach, 1998.

David S. Steinberg, Cooling Techniques for Electronic Equipment, 1991.

Cooling Techniques for Electronic Equipment

Second Edition

Dave S. Steinberg

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that larger pumps and fans and more power be used to overcome the added resistance.

6.2 COOLING AIRFLOW DIRECTION FOR FANS

When a fan is used for cooling electronic equipment, the airflow direction can be quite important. The fan can be used to draw air through a box or to blow air through a box. A blowing fan system will raise the internal air pressure within the box, which will help to keep dust and dirt out of a box that is not well sealed. A blowing system will also produce slightly more turbulence, which will improve the heat transfer characteristics within the box. However, when an axial flow fan is used in a blowing system, the air may be forced to pass over the hot fan motor, which will tend to heat the air as it enters the electronic box, as shown in Figure 6.1.

An exhaust fan system, which draws air through an electronic box, will reduce the internal air pressure within the box. If the box is located in a dusty or dirty area, the dust and dirt will be pulled into the box through all of the small air gaps if the box is not sealed. In an exhaust system, the cooling air passes through an axial flow fan as the air exits from the box, as shown in Figure 6.2. The cooling air entering the electronic box is therefore cooler.

The position of the fan blades within an axial flow fan housing can be a critical factor in determining how well a fan will perform. This is especially important in high-speed fans that have speeds greater than about 8000 rpm.

An examination of most high-speed axial flow fans will show that the fan blades are not located at the center of the tubular housing but near one end. When the fan is located adjacent to a restricted area, such as a 90° bend, the fan blades should be positioned so that they are at the downstream end of the housing, for the best performance. Air has weight and kinetic energy, so that the air velocity must be allowed to develop to effectively overcome the flow resistance. When the fan blades

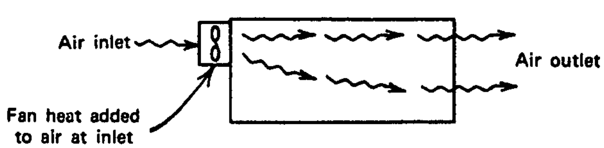

Figure 6.1 *Axial flow fan blowing cooling air through a box.*

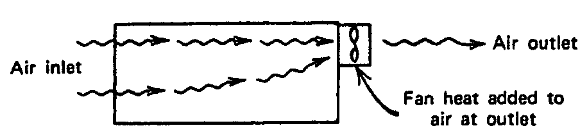

Figure 6.2 *Axial flow fan drawing cooling air through a box.*

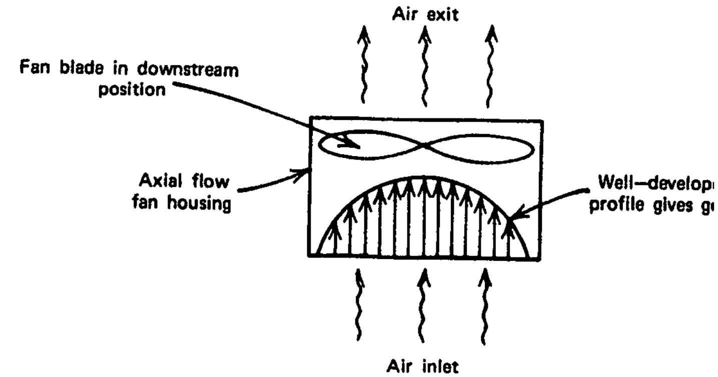

Figure 6.3 *Well-developed velocity profile in an axial flow fan*

are located at the downstream end of the fan housing, the air has a s flow path. This improves the velocity profile, as shown in Figures 6

It makes no difference if a blowing or an exhaust fan system is usec profile must have a chance to develop to provide an efficient air deli

The reduced flow efficiency for the fan shown in Figure 6.4 will n to a casual observer. When the fan is in operation, you can place yc the exhaust and feel a large volume of air flowing through the fan. I thin strip of paper is slowly passed across the fan exhaust, it will sh of the air is being short-circuited. The airflow at the outer perimeter c be moving away from the fan, but the airflow at the center will be m the fan, resulting in a short circuit, as shown in Figure 6.5.

Some good fan installations and some poor ones are shown in Fig data on these types of installations have shown that the cooling airflo more than doubled just by properly orienting the position of the fan the fan housing when the fan is located adjacent to an area that rest flow of cooling air.

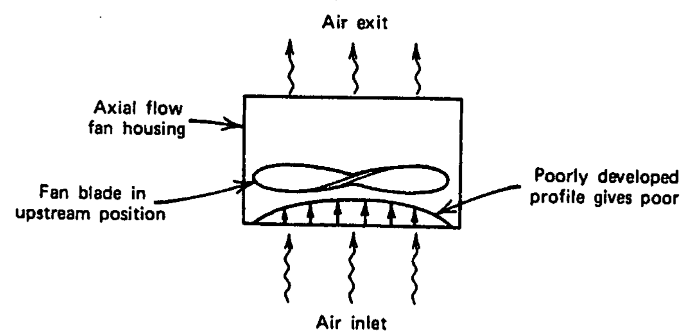

Figure 6.4 *Poorly developed velocity profile in an axial flow fan*

6.28 DIRECT AIR IMPINGEMENT COOLING

The standard method for cooling large racks and cabinets has been to provide a blower at the bottom of the cabinet that blows cooling air upward through large vertically oriented plug-in PCBs spaced slightly more than 1 in apart. The PCB spacing will depend upon the height of the electronic components. The PCBs form ducts that guide the cooling air to the top of the cabinet where the air is exhausted, as shown in Figure 6.47.

The problem with this cooling method is that the air at the top of the cabinet is much hotter than the air at the bottom of the cabinet, because the air picks up heat as it passes over the PCBs and the hot components. In addition, where large components are upstream from small components, the cooling airflow may be blocked so the small components are not cooled properly. These types of problems can often be avoided by using a direct cooling air impingement method for removing the heat from the electronic assembly [54, 55].

The direct air impingement cooling method works best on PCBs that utilize high-power-dissipating pin grid arrays (PGAs) and DIPs. The standard cabinet cooling arrangement can still be used where the blower is mounted at the base of the cabinet, with the cooling air directed upward toward the vertically oriented PCBs. At this point the systems change. In the direct air impingement method, the cooling air is directed into a flat, slim plenum that is immediately adjacent and parallel to each PCB. The plenum has special openings and orifices located directly opposite the high-heat-dissipating components on the plug-in PCBs, which forces

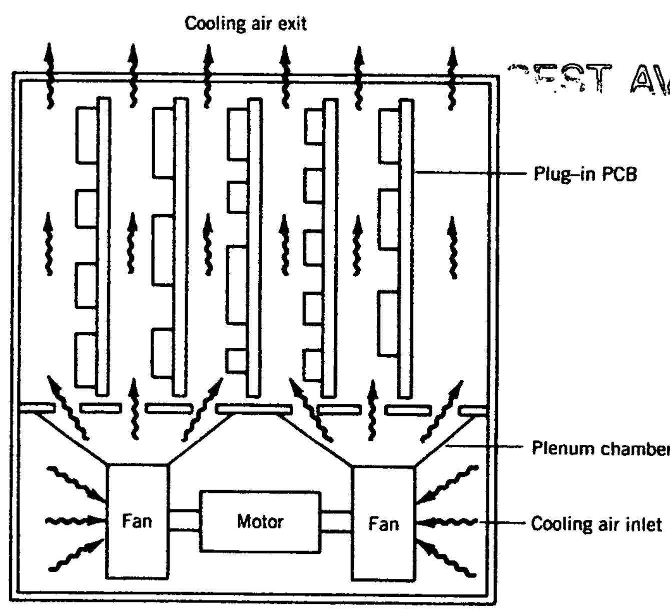

Figure 6.47 Standard cooling system for a large cabinet.

HEAT TRANSFER

A PRACTICAL APPROACH

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otted against the flow rate of air. Note that a fan creates the *highest* pressure ɜad at *zero* flow rate. This corresponds to the limiting case of blocked exit ɜnts of the enclosure. The flow rate increases with decreasing static head ıd reaches its maximum value when the fan meets no flow resistance.

Any electronic enclosure will offer some resistance to flow. The system ɛsistance curve is *parabolic* in shape, and the pressure or head loss due to ıis resistance is nearly proportional to the *square* of the flow rate. The fan ıust overcome this resistance to maintain flow through the enclosure. The ɜsign of a forced convection cooling system requires the determination of ıe total system resistance characteristic curve. This curve can be generated ːcurately by measuring the static pressure drop at different flow rates. It can so be determined approximately by evaluating the pressure drops.

A fan will operate at the *point* where the fan static head curve and the 'stem resistance curve *intersect*. Note that a fan will deliver a higher flow ıte to a system with a low flow resistance. The required airflow rate for a 'stem can be determined from heat transfer requirements alone, using the ɜ*sign heat load* of the system and the *allowable temperature rise* of air. hen the flow resistance of the system at this flow rate can be determined ıalytically or experimentally. Knowing the flow rate and the needed pres- ıre head, it is easy to select a fan from manufacturers' catalogs that will ıeet both of these requirements.

Below we present some general guidelines associated with the forced-air ɔoling of electronic systems.

. Before deciding on forced-air cooling, check to see if *natural convection* ɔoling is adequate. If it is, which may be the case for low-power systems, corporate it and avoid all the problems associated with fans such as cost, ɔwer consumption, noise, complexity, maintenance, and possible failure.

Select a fan that is neither too small nor too large. An *undersized* fan ay cause the electronic system to overhead and fail. An *oversized* fan will ɜfinitely provide adequate cooling, but it will needlessly be larger and more ːpensive and will consume more power.

If the temperature rise of air due to the power consumed by the motor of e fan is acceptable, mount the fan at the *inlet* of the box to pressurize the ɔx and filter the air to keep dirt and dust out (Fig. 14-48).

Position and size the air exit vents so that there is *adequate airflow* roughout the entire box. More air can be directed to a certain area by ılarging the size of the vent at that area. The total exit areas should be at ast as large as the inlet flow area to avoid the choking of the airflow, which ay result in a reduced airflow rate.

Place the most critical electronic components near the *entrance*, where e air is coolest. Place the components that consume a lot of power near the ːit (Fig. 14-49).

Arrange the circuit boards and the electronic components in the box such at the *resistance* of the box to airflow is *minimized* and thus the flow rate of

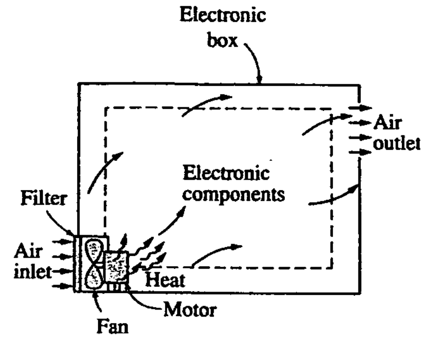

FIGURE 14-48

Installing the fan at the inlet keeps the dirt and dust out, but the heat generated by the fan motor in.

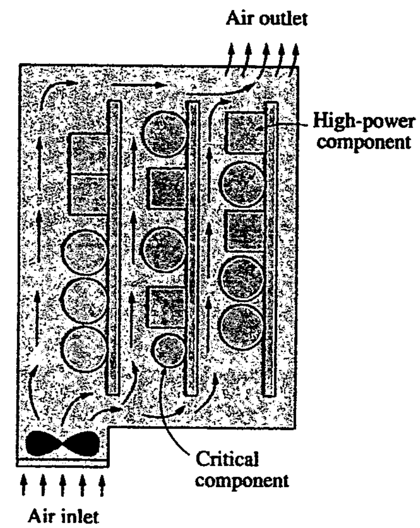

FIGURE 14-49

Sensitive components should be located near the inlet and high-power components near the exit.

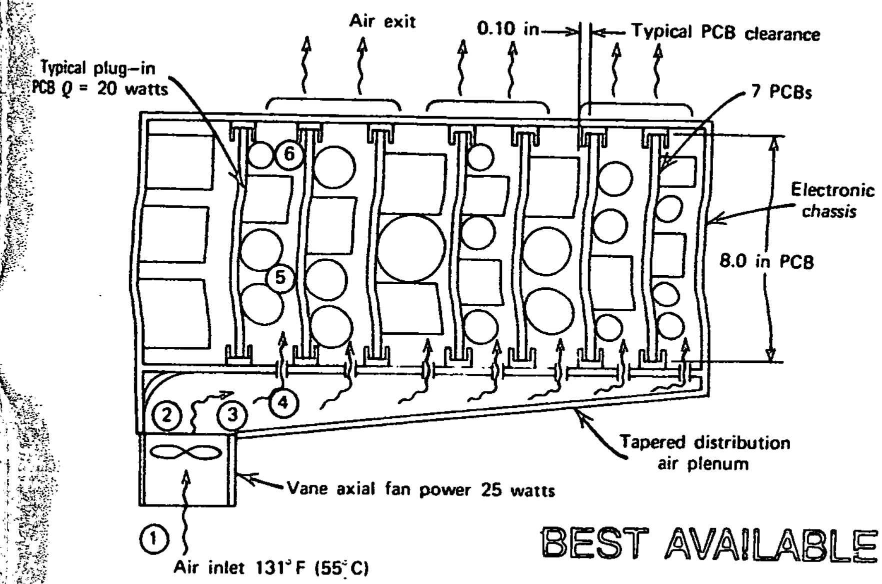

Figure 6.13 Plan view of fan-cooled electronic box.

required. The preliminary analysis can also be used to establish an approximate fan size.

The maximum allowable temperature rise from the air inlet to the component surface hot spot temperature is 212°F − 131°F = 81°F (100°C − 55°C = 45°C). There are two major contributors to this temperature rise.

1 Δt due to the heat input from the fan and the electronics to the cooling air.
2 Δt due to the thermal resistance across the convection film from the cooling air to the surface of the component.

These temperature rise sources can be examined in more detail to see how much each contributes to the total value.

Δt due to the Heat Input from the Fan and the Electronics to the Cooling Air

Heat generated by the fan motor is usually removed by convection from the cooling air. If the fan is bolted to a large heat sink away from the electronic box, a large part of the heat from the fan motor may be removed by direct conduction and radiation from the fan housing to the heat sink.

When the fan is bolted directly to the chassis that houses the electronics, the chassis walls may be quite hot, so relatively little fan heat may be transferred to the chassis. Therefore, it is a good practice to be slightly conservative and to assume that all of the fan power will be picked up by the cooling air as it passes through the fan and into the chassis housing.